Countability: Individuation and Context

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Abstract. Much of the recent countability research agrees on the idea that a satisfactory account of *individuation* in terms of what counts as "one" unit for counting is highly relevant for characterizing a semantics of the mass/count distinction. (What counts as "one" is not necessarily a formal atom in a Boolean algebra or a natural unit associated with natural kinds like *cat*.) Taking the most parsimonious stance, our main question is: If we have a full-fledged formal theory of individuation (what counts as "one"), what data would still remain to be explained for a formal theory of the mass/count distinction? Would classical mereology be sufficient to cover such data? And, if not, what minimal extensions would be required to classical mereology to do so? We conclude that, minimally, two dimensions of context sensitivity are needed to enrich a mereological semantics of count nouns denotations. The first kind of context sensitivity enables counting operations to apply by removing overlap from an overlapping set of individuated entities. The second kind of context sensitivity allows us to motivate how a set of individuated entities can sometimes be taken as a counts as "one" despite not being a formal atom or a natural unit associated with a natural kind.

Keywords: Mass/count distinction · Mereology · Individuation · Overlap · Context sensitivity

1 Introduction: From Atomicity to Counting as 'One'

Early proposals regarding the nature of the mass/count distinction, many of which are inspired by Quine (1960), attempt to distinguish mass and count noun denotations rely on properties like cumulativity, divisivity, atomicity, and homogeneity.[1] In mereological theories, starting with Link (1983) and Krifka (1989), they were recast as second-order predicates and defined as follows:

$$AT(P) \leftrightarrow \forall x[P(x) \rightarrow \exists y \forall z[P(y) \wedge (P(z) \rightarrow \neg(z \sqsubset y))]] \quad (1)$$

$$CUM(P) \leftrightarrow \forall x \forall y[(P(x) \wedge P(y)) \rightarrow P(x \sqcup y)] \quad (2)$$

$$DIV(P) \leftrightarrow \forall x \forall y[(P(x) \wedge y \sqsubset x) \rightarrow P(y)] \quad (3)$$

Link (1983) proposes a sortal distinction between count and mass nouns, based on the atomic/non-atomic ontological distinction which is modeled by

[1] Also see Pelletier (1979) and references therein.

A. Foret et al. (Eds.): FG 2015/2016, LNCS 9804, pp. 290–305, 2016.
DOI: 10.1007/978-3-662-53042-9_17

means of atomic and non-atomic semilattice structures. Count nouns are interpreted in the atomic lattice, while mass in the non-atomic one. Mass nouns pattern with plurals in being cumulative. Mass nouns and plurals also pattern alike in being divisive (down to a certain lower limit). However, none of these properties turned out to be either necessary or sufficient conditions for underpinning the mass/count distinction. For example, mass nouns such as *furniture* are atomic, count nouns such as *fence* pattern with mass terms in being divisive and cumulative (modulo contextual restrictions).

Krifka (1989) rejects Link's sortal 'dual-domain' approach on which count and mass nouns are interpreted in two different domains. Instead, his strategy is to combine the notion of a single complete join semi-lattice (a general partial order), which structures a single domain of objects, with the notion of an extensive measure function, which serves to derive quantized semantic predicates; such predicates fail to be divisive, and hence are count. The lexical semantic structure of basic lexical count nouns like *cat* contains the extensive measure function NU (for 'Natural Unit'), which does the "individuating job" of determining singular clearly discrete objects in their denotation. But this means that basic lexical count nouns are quantized, and fail to be divisive. This strategy amounts to a typal distinction between count and mass nouns.

As Zucchi and White (1996, 2001) show, there are count nouns like *twig, sequence, fence* which fail be quantized. Problematic for Krifka's account are also superordinate (aka object) mass nouns like *furniture*, because they have 'natural units' in their denotation, like stools, coffee tables, chairs. Indeed, object mass nouns like *furniture* pose problems even for more recent accounts. For example, Chierchia (2010) argues that mass nouns differ from count nouns in having vague ("unstable") minimal individuals in their denotation, but this means that he is forced to claim that the mass behavior of object mass nouns is not due to the vagueness of minimal elements in their denotation, but require an alternative explanation.

In some recent work (Rothstein 2010; Landman 2011; Grimm 2012; Sutton and Filip 2016), it has been argued that a formal representation of what counts as "one" is needed, which is not based on the notion of a 'natural unit' in any sense. For example, Rothstein (2010) argues that there are count nouns like *fence, wall* which fail to be naturally atomic, and are divisive. Their grammatical count behavior is motivated by the assumption that their denotation is indexed to counting contexts with respect to which what is "one" entity in their denotation is determined. Landman (2011) proposes that mass nouns have overlapping sets of entities that count as "one", his "generator sets", in their denotation, while count nouns have non-overlapping generator sets. Grimm, just like Rothstein and Landman, presupposes the assumptions of a classical extensional mereology, but enriches it with topological notions. Countable entities have the mereotopological property of being *maximally strongly self connected*. Sutton and Filip (2016) argue that both vagueness with respect to what counts as "one" and non-overlap in the set of entities that count as "one" interact in such a way as to either block or facilitate variation in mass/count encoding.

However, as we shall argue, even with a formal representation of what counts as "one", that is, a formal account of *individuation*, we do not have a satisfactory account of the grounding of the mass/count distinction. In this paper, we will point out some weaknesses of such an account, and seek to clarify what, in formal terms is minimally required to model the mass/count distinction in a more adequate way. Our strategy is to proceed in the most parsimonious way and answer the following fundamental questions: If we have a full-fledged formal theory of individuation (what counts as "one"), what data would still remain to be explained for a formal theory of the mass/count distinction? Would classical mereology be sufficient to cover such data? And, if not, what minimal extensions would be required to classical mereology to do so?

In Sect. 2, we identify a number of classes of nouns that have been given a lot of attention in the countability literature and outline the sense in which these nouns individuate entities into what counts as "one". We then schematize these results in mereological terms and suggest that concrete nouns form at least four individuation patterns. The result, we argue, is that the mass/count distinction cuts across the individuated/non-individuated divide. In Sect. 3, we relate key recent research into theories of individuation and the mass/count distinction to discuss which formal enrichments have been suggested as necessary for a theory of individuation. In Sect. 4, we propose that classical mereology must be minimally extended with two separate conceptions of context in order to cover the data that are intractable within formal theories relying on the notion of individuation.

2 Individuation Patterns Across Classes Of Nouns

Considering just concrete nouns, we may distinguish five classes of nouns depending on their main lexicalization patterns. They are summarized in Table 1, where the 'Noun Class' is a cover term for the descriptive labels below it.[2]

All accounts of the mass/count distinction at least aim to cover nouns that we describe as "prototypical objects" (*chair*, *boy*) and as "substances, liquids and gasses" (*mud*, *blood*, *air*). Indeed, an absolutely minimal requirement on any account of the mass/count distinction is that it can at least semantically distinguish between these two classes.

2.1 Prototypical Objects

Nouns in the *prototypical objects* category are what have been called "naturally atomic" (see e.g., Rothstein 2010, and references therein). With these nouns, the

[2] A notable omission from Table 1 are so-called "dual life" nouns such as *stone*$_{+C}$/*stone*$_{-C}$ ($+C$ abbreviates COUNT and $-C$ abbreviates MASS). We leave these aside in this paper, given that it is unclear whether one should take either the mass or count sense to be primary, or, indeed, whether such nouns should be classified as being of some intermediary morphosyntactic category between count and mass.

Table 1. Classes of nouns and mass/count variation

Noun class	Examples
Proto-typical objects	*chair*$_{+C}$; *tuoli*$_{+C}$ ('chair' Finnish); *Stuhl*$_{+C}$ ('chair' German) *dog*$_{+C}$; *koira*$_{+C}$ ('dog' Finnish); *Hund*$_{+C}$ ('dog' German) *boy*$_{+C}$; *poika*$_{+C}$ ('boy' Finnish); *Junge*$_{+C}$ ('boy' German)
Super-ordinate artifacts	*furniture*$_{-C}$; *huonekalu-t*$_{+C,PL}$ ('furniture' Finnish) *meubel-s*$_{+C,PL}$, *meubilair*$_{-C}$ ('furniture' Dutch) *kitchenware*$_{-C}$; *Küchengerät-e*$_{+C,PL}$ (German, lit. kitchen device-s) *footwear*$_{-C}$; *jalkinee-t*$_{+C,PL}$ ('footwear' Finnish)
Homogenous objects	*fence*$_{+C}$, *fencing*$_{-C}$; *hedge*$_{+C}$, *hedging*$_{-C}$ *wall*$_{+C}$, *walling*$_{-C}$; *shrub*$_{+C}$, *shrubbery*$_{-C}$
Granulars	*lentil-s*$_{+C,PL}$; *linse-n*$_{+C,PL}$ ('lentils' German) *lešta*$_{-C}$ ('lentil' Bulgarian); *čočka*$_{-C}$ ('lentil' Czech) *oat-s*$_{+C,PL}$; *oatmeal*$_{-C}$; *kaura*$_{-C}$ ('oat' Finnish); *kaurahiutale-et*$_{+C,PL}$ (Finnish, lit. oat.flake-s)
Substances, liquids, gases	*mud*$_{-C}$; *muta*$_{-C}$ ('mud' Finnish); *Schlamm*$_{-C}$ ('mud' German) *blood*$_{-C}$; *veri*$_{-C}$ ('blood' Finnish); *Blut*$_{-C}$ ('blood' German) *air*$_{-C}$; *lenta*$_{-C}$ ('air' Finnish); *Luft*$_{-C}$ ('air' German)

"natural units", or the entities we would count as "one" are just the minimal entities in their denotations for which nothing else in the denotation is a proper part, i.e., they are quantized in the sense of Krifka (1989). As Table 1 shows, nouns in these classes display a strong tendency to be lexicalized as count as in confirmed by the felicity and grammaticality of direct modification with numerical expressions (such as the Finnish example in (4) and its English translation).

(4) Kolme tuoli-a/koira-a/poika-a.
Three chair-PART dog-PART boy-PART.
"Three chairs/dogs/boys".

Assuming that count nouns take their interpretation from an atomic join semilattice, the denotation of prototypical objects is represented in Fig. 1: the basic (extensional) meaning of a count noun is a number neutral property and hence its denotation comprises the whole lattice; the shaded area highlights the set of singular (atomic) entities that count as "one".

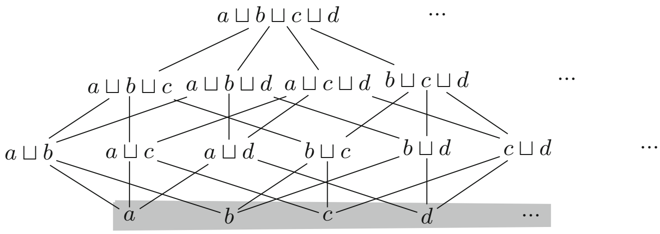

Fig. 1. Prototypical objects: Individuals are disjoint bottom elements

2.2 Substances, Liquids and Gasses

Prototypical mass nouns tend to denote *substances, liquids and gasses*. In stark contrast to prototypical objects, nouns in this class lack any clear individuable entities/units at all. That is to say, whether or not one assumes the denotations of these nouns are defined over atomic or non-atomic semilattices, there are no entities that "stand out" as individuals (things that count as "one").

Nouns in this class are very stably lexicalized as mass cross- and intralinguistically. For example, as the German example in (5) and its English translation show, direct numerical modification is infelicitous in the absence of a classifier-like expression.

(5) # Vier Lüft-e/Schlämm-e.
four air-PL/mud-PL
"Three bloods/airs".

We schematize the denotation of nouns describing substances, liquids and gasses as in Fig. 2. Unlike Fig. 1, there is no shaded area for entities that count as "one" clearly individuated atomic unit.

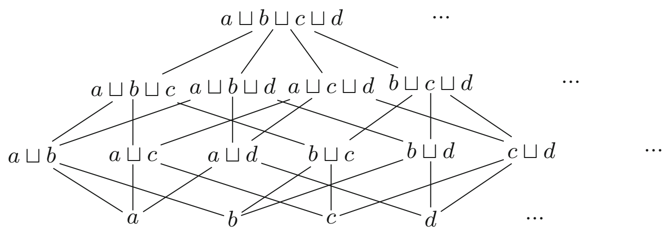

Fig. 2. Substances: No individuals

2.3 Superordinate Artifacts

Superordinate artifacts are among the three categories in between *Prototypical Objects* and *Substances, Liquids, and Gasses* nouns, the two extreme poles of a countability scale (see also Allan 1980), along with *Homogenous Objects* and *Granulars*. These three classes are far more complex than *Prototypical Objects* and *Substances, Liquids, and Gasses* and all display cross and intralinguistic count/mass variation.

Nouns in this class have been variously labelled "fake mass nouns", "superordinate aggregates", "object mass nouns", "neat mass nouns", however arguably superordinate count nouns such as *vehicle* should also fall in the same grouping. A well known puzzle with such nouns is why so many languages lexicalize them as mass nouns at all. The denotations of these nouns have clearly individuable entities at the 'bottom' of them which should *prima facie* be good candidates for counting, and superordinacy in itself is no bar to countability (as evidenced by count nouns such as *vehicles*, *fruits* (US English), *vegetables*).

Nonetheless, one may find both mass and count nouns in this category with both cross- and intralinguistic variation. For example, the grammaticality of the Finnish example in (6) contrasts with the complete infelicity of the English (7).

(6) Kaksi huonekalu-a.
two furniture-PART
"Two items of furniture".

(7) ## Two furnitures

What counts as "one" for nouns in this category is not, however, restricted to entities at the bottom of the lattice (as is the case with prototypical objects). As observed by Landman (2011), sums of minimal entities may also count as "one". For example, for *kitchenware*, a teacup and a saucer count as "one" item of kitchenware, but in many contexts, so might a teacup and saucer together, and, for *furniture*, tables/desks, stools/chairs and mirrors all count as single items of furniture, but so does a vanity formed of one of all three. This pattern is schematized in Fig. 3. The minimal entities that count as "one" are shaded in darker gray. The rest of the lattice is also shaded, but the lighter color indicates that some, but not necessarily all sums of minimal entities count as "one".

2.4 Homogenous Objects

This class includes nouns such as *fence* and *fencing*. We use 'homogenous' here in the sense of Rothstein (2010). For example, for some entities that count as fences, proper parts of these entities themselves count as fences. Note that such nouns denote divisive predicates in the sense of (3) above (down to a certain lower limit). These nouns are cumulative, even with respect to what counts as "one". For example, if two fences are attached together, then there will be contexts in which their sum counts as a single fence.

One difference between homogenous objects and superordinate artifacts is that, at least for some nouns in this class, there seem to be fewer restrictions on what can be put together to count as "one". This derives from the homogeneity of these objects, as opposed to the more functionally defined homogenous artifacts.

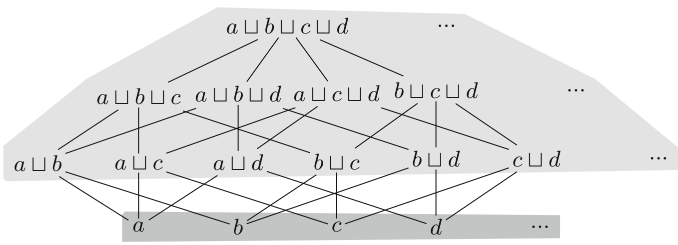

Fig. 3. Superordinate artifacts and homogenous objects: Individuals are disjoint bottom elements plus at least some sums thereof

A whisk and a teaspoon cannot, at least in ordinary contexts, count as a single item of kitchenware since the two together do not *function* as a single item. A pestle and mortar can count as a single item of kitchenware, since these two do have a joint function with respect to being a kitchenware tool. For fences and bushes, however, provided that two or more portions of fencing/hedge are relevantly similar, one can be appended to the other to make what could count as a single fence/hedge. Nonetheless, it is not the case that, for example, any two entities in the denotation of *fence* could be put together to form one fence. It is hard to imagine how a 50 cm high picket fence and a 4 m high chainlink fence could count as "one". For this reason, we schematically represent homogenous objects in the same way as superordinate artifacts in Fig. 3.

For at least some languages with count/mass counterparts in this category such as English and German, the morphologically simple item tends to be count (*hedge*, *Busch* ('bush'/'shrub', German)) and a morphologically more complex item formed from this root tends to be mass (*hedging*, *Gebüsch* ('shrubbery' German)).

2.5 Granulars

Granulars align roughly with what Grimm (2012) labels "collective aggregates". These tend to be formed of collections of similar items with food items as common examples (*rice, lentils, beans*), however other examples include *shingle*, *gravel*, *pebbles*. Their denotation most obviously, from a perceptual perspective, consists of non-overlapping grains, flakes, granules and the like. Furthermore, whenever one finds a count noun in this class, it is precisely the single flakes, grains or granules that are denoted by the singular form.

However, parts of these grains, flakes or granules are also in the number neutral denotations of these nouns. For example, rice flour counts as rice, and red lentils, after cooking down into a kind of pulp, still count as *lentils*. This pattern of the relationship between the regular denotation and what counts as "one" is schematized in Fig. 4. To reflect that these nouns are granular, the individuated entities are disjoint (non-overlapping), but are not at the bottom of the lattice. A pile of broken up rice grains or lentils still count as *rice* or *lentils*, respectively. This category also displays a large amount of count/mass variation as Table 1 helps to show.

2.6 Individuation Does Not Determine Mass/Count Encoding

With these four individuation patterns outlined,[3] it should be clear that being individuated in the sense of having entities that count as "one" or not is insufficient for determining whether nouns are count or mass. We grant that the only completely non-individuated class tends strongly towards containing only mass nouns, but superordinate artifacts, homogenous objects, and granulars all contain many examples of both mass and count nouns.

[3] We do not rule out there being more than these four.

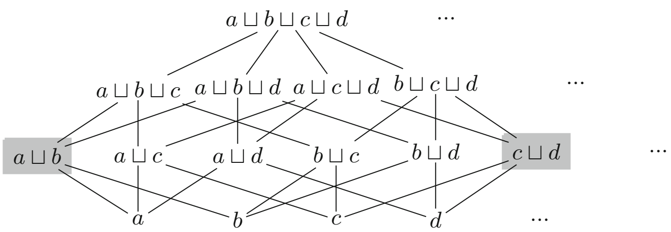

Fig. 4. Granulars: Individuals are non-bottom, disjoint individuals

Notice too, that being individuated is not the same as coming in natural units. Sums of fence units can still count as *one fence*, and collections of items of kitchenware such as pestles and mortars can still count as *one item of kitchenware* or as *ein Küchengerät* ('one (item of) kitchenware', German).

3 Enrichments Needed for a Theory of Individuation

The four patterns of individuation we have just outlined could be understood as the outcome of some fully-fledge theory of individuation. In Sect. 4, where we make the main point in this article, we will show that even after assuming such a fully fledged theory of individuation has already been given, the basic tools of mereology are insufficient for accounting for count/mass variation data. Specifically, we argue that at least two contextual parameters must be added to classical mereology and a theory of individuation to accommodate these data.

However, within the count/mass literature, these issues of individuation and the count/mass distinction are not always articulated. Also, suggestions for enrichments to mereology have been made, such as mereotopology (Grimm 2012), context sensitivity (Rothstein 2010) and vagueness (Chierchia 2010). Therefore, in this section we review some of these suggested enrichments, and point out which pertain to a theory of individuation (defined as producing at least the four patterns above), and which develop a theory of the count/mass distinction on top of and further to the issue of individuation.

The reason for pursuing this line is that the mass/count distinction cuts across the individuated/non-individuated divide, as the schemas in Figs. 1, 2, 3 and 4 show. For example, even though homogenous objects, superordinate artifacts and granulars are all individuated, some of these nouns are count, and others are mass.

3.1 Mereotopology

The schema in Fig. 1 for prototypical objects is a standard representation of the denotation for a count noun, however, given a single domain assumption on which all nouns are interpreted relative to the same domain, it actually hides a wealth of assumptions. If we assume a single general domain, with respect to which the denotations of predicates are defined, then most common concrete count nouns will not have, as atoms at the bottom of their denotations, entities which are atoms with respect to the whole domain. This is a point one can find in the background of Rothstein (2010) where formal atoms of the domain need not be specified to give an account of the semantic atoms (things that count as 'one') for a predicate, and it is explicit in recent work from Landman (Landman 2015). However, this means that, for example, the $a, b, c, d, \ldots$ in Fig. 1 are atoms relative to a predicate, but not necessarily formal atoms in the whole domain. For example, if the domain contains chair backs, chair seats, and chair legs, the denotation of *chair* will contain, as individuated entities, entities that are, formally, sums of chair parts. Now, if one accepts this characterization, then certain arguments, such as those employed in Grimm (2012), gain some traction.

Grimm (2012) argues that classical mereology is not sufficient for characterizing individuals. This is because, in classical mereology, all sums are equal. That is to say that the sum of any two entities is considered to be a mereological entity in its own right. However, many sums are not good candidates to be individuals. For example, the sum of Donald Trump and a Blancmange sitting a thousand miles away does not make for a good candidate to be an individual. Less bizarrely, even if we were to pile an assortment of chair legs, a chair back and a chair seat together, we do not have a chair individual, or if we took a sum of twenty starlings, they would not make a flock unless reasonably proximate. Taking these considerations seriously suggests that a formal theory of individuation must involve not only mereological relations, but also topological ones (mereotopology). The need for mereotopology can also be seen in Fig. 4. For granular nouns, we have assumed in that what counts as "one" are the (whole) grains or granules. For example, single lentils count as "one" with respect to the predicate *lentil*. However, if the number neutral property for *lentil* also denotes parts of lentils and lentil flour, then only a privileged selection of sums will be whole lentils (hence the highlighting of $a \sqcup b$ and $c \sqcup d$, but not, at the same time, e.g. $a \sqcup d$ in Fig. 4). Similarly, the things we would count as "one" for homogenous objects can be affected by mereotopological factors too. If two box bushes are placed in close enough proximity, they may count as a single hedge/bush, but not if they are too far apart.

Mereotopology, as an enrichment of mereological semantics, therefore best addresses the issue of individuation (what counts as "one"). Indeed, there is good reason to assume that the four individuation patterns above could not be provided without some appeal to topological relations. For the remains of this paper, we therefore view the topology in 'mereotopology' as part of a theory of individuation. This will allow us to ask what, beyond individuation and mereology, we need to account for patterns in count/mass variation.

3.2 Vagueness and Underspecification or Overspecification

For substances, liquids and gasses, there are no entities that intuitively count as "one". This loosely reflects a general consensus in the semantics of countability literature, but the details differ. For example, Chierchia (1998, 2010), and

Rothstein (2010) appeal to vagueness or underspecification with respect to what the atoms of prototypical mass nouns are. In other words, for example, there are no entities that count as "one" *mud*, because the meaning of mud does not determine or specify such a set.

An alternative position, defended by Landman (2011) is overdetermination. On this view, it is not quite right to say that there are no entities that count as "one" for substances, liquids and gasses, but rather that there is no single set of entities that count as "one". There are, on this view, many ways one could cut the cake and so no single way to count. With more than one way to count where the answer to the question 'how many' depends on the way one does count, then counting goes wrong.

We do not wish to argue in favor of over- or underdetermination here. What matters is that these enrichments to one's model are needed already to form an account of individuation. It remains to be seen, however, whether under/overdetermination will still be needed for a theory of countability if a theory of individuation is taken as basic.

3.3 Context Sensitivity

The need for context sensitivity in a theory of individuation comes from two sources. First, there are data from Yudja, a language in which, it is argued, all nouns can be directly attached to numerals and then counted (Lima 2014). In the examples cited by Lima (2014), counting with substances, liquids and gasses, for example *apeta* ('blood', Yudja), was assessed in relation to a context. Informants were shown pictures as contexts. The portions of blood, sand etc., are clearly separated, albeit not always the same size or quantity and were reliably described these situations using direct numeral attachment to nouns in this class. Lima argues that such constructions are not coercions from mass interpretations into conventional packaged units. It is not so contentious, therefore, to assume some form of context dependency for what counts as "one" for nouns in the substances, liquids and gasses category in Yudja. That is to say that Yudja speakers do seem to individuate substances, liquids and gasses albeit in a context dependent way. Such a role for context sensitivity, namely determining when portions of substances are sufficiently spatially demarcated to count as "one", would, on our terms, be part of a theory of individuation.[4]

Second, vague, but nonetheless countable nouns such as *heap*, *fence*, and *mountain* provide some evidence for context-sensitivity in what counts as "one". Chierchia (2010), in the context of arguing that it is vague what the countable entities in the denotations of mass nouns are, claims that nouns such as *fence* are not vague in the same way. Although it might be vague what the smallest fence unit is, just as it is famously vague, via sorites arguments, at how many grains a heap becomes a non-heap, this vagueness is different from the underspecification of what the atoms for a noun such as *mud* are. The point, simply put, is that there

[4] We do not view this role for context as the same as that employed by Rothstein (2010) which specifies what is lexically accessible for counting in context.

are clear cases of mountains, fences and heaps, and so, provided that one sets what Chierchia calls a "ground context", one can be assured of, for example, a set of non-overlapping minimal fence units at every ground context. This claim strongly resembles one made by Rothstein (2010) who argues that "counting context" dependency should be encoded into the semantics of count nouns so as to capture the countability of nouns such as *fence* and *twig*. In other words, there is a element of context that determines what counts, minimally, as fences or twigs. It is important to note that the same applies for mass nouns such as *fencing*. What counts minimally, as an item of fencing may vary with context. This role for context more clearly applies to the count/mass distinction that to only a theory of individuation. We will return to this role for context in Sect. 4.

3.4 Summary

Our list of mereotopology, underspecification/vagueness, overspecification, and context sensitivity is surely not exhaustive of the formal devices needed for a full account of individuation. For example, for artifacts such as *chair* as well as superordinate artifacts such as *furniture*, some form of lexical semantic representation of function will probably be needed. However, what we have aimed to do thus far is clear the decks of some of the complications involved in the semantics of the mass/count distinction. In the next section, we assume that some account of individuation can be given and so the schemas in Figs. 1, 2, 3 and 4 can be taken for granted. As we have just seen, providing a fully-fledged theory of individuation would be a highly complex and detailed task. Therefore, our assumption that one can be adequately given is a substantial simplifying assumption.

Let us henceforth suppose that there is a fully-fledged theory of individuation that predicts the four individuation patterns from Sect. 2. This means that having entities that count as "one" is not a sufficient condition for being a count noun, but it also enables us to ascertain how far we can proceed in specifying the mass/count distinction in purely mereological terms once a theory of individuation is taken as basic.

4 Applying Mereology to the Noun Classes

4.1 Formally Characterizing the Noun Classes in Mereological Terms

Since the domain is, as standardly assumed in mereological semantics, a Boolean algebra minus the empty set, we can say the following about the relationship between the denotations of all classes of nouns and the set of entities that count as "one". We assume that $Ind(P)$, denotes the set entities that count as "one" P. This is licensed because at this point we are assuming that a fully-fledged account of individuation along with classical mereology.

On these assumptions, being a P-individual is a sufficient condition for being P:

$$\forall P \forall x[Ind(P(x)) \rightarrow P(x)] \tag{8}$$

(8) is trivially satisfied by substances, liquids and gasses, which have no entities that count as "one", and is non-trivially satisfied for all other noun classes.

Another property that can be seen is with respect to the distributional properties of mass and count nouns amongst these classes. As noted in Sect. 2, substances, liquids and gasses are in all but rare cases lexicalized as mass nouns. A notable exception is Yudja (Lima 2014), which appears to allow direct counting with all nouns. All other noun classes, which have non-empty *Ind* sets contain some nouns lexicalized as count. This suggests that individuation (being able to identify what counts as "one") is a necessary, but not sufficient condition for countability, and lacking individuated entities is a sufficient condition for being uncountable.[5] In other words, if C is a second order property of predicates (being countable), such that $\Diamond C$ means possibly countable and $\Box \neg C$ means necessarily not countable:

$$\forall P[\Diamond C(P) \leftrightarrow \exists x[Ind(P(x))]] \tag{9}$$

$$\forall P[\Box \neg C(P) \leftrightarrow \neg \exists x[Ind(P(x))]] \tag{10}$$

The intuitive explanation for why (9) should make the lexicalization of a count noun possible is that individuation, finding at least some individuals in a noun's denotation, is the first minimal step towards being able to count. Otherwise, there would be nothing to count.

However, we may also describe a property held by the three classes of nouns which display variation. In other words, for a predicate P we can describe when mass/count variation is to be expected ($\Diamond C(P) \wedge \Diamond \neg C(P)$), and, by negation of both sides of the biconditional, when it is not permitted ($\Box C(P) \vee \Box \neg C(P)$).

$$\forall P[\Diamond C(P) \wedge \Diamond \neg C(P) \leftrightarrow \exists x \exists y[Ind(P(x)) \wedge P(y) \wedge y \sqsubset x]] \tag{11}$$

$$\forall P[\Box C(P) \vee \Box \neg C(P) \leftrightarrow \forall x \forall y[(Ind(P(x)) \wedge P(y)) \rightarrow \neg y \sqsubset x]] \tag{12}$$

In words, it turns out that mass/count variation is licensed when a particular kind of relationship exists between members of the set of Ps and members of the set of P individuals. For superordinate artifacts, homogenous objects, and granulars, there are entities in the set of Ps that are proper parts of entities in the set of P individuals. Examples of this are summarized in Table 2. For prototypical objects this is not so, since, vagueness aside, parts of boys, cats and

[5] This would require taking the view that in Yudja, a more liberal view is taken on what counts as "one" such that nouns denoting, for example, *mud* would have non-empty *Ind* sets. This may be relative to some specific context only, however. The examples for counting with nouns denoting substances and liquids in Lima (2014) tend to be in contexts where there are clearly perceptual portions involved such as drops of blood.

chairs are not boys, cats and chairs, respectively.[6] It is also not the case that substances, liquids and gasses have entities in their denotations that are parts of individuals, since they have empty *Ind* sets.

The question is why should the property in (11) facilitate the possibility of either mass or count encoding and its negation in (12) prevent it? Furthermore, we may ask whether such an explanation needs to appeal to more than just mereological relations and properties. In the remains of this section, we show how far we consider one can get with mereology alone. In Sect. 4.2, we then argue that simple mereology is insufficient for providing a satisfactory analysis of countability.

Since, of recent accounts, Landman (2011) remains truest to a purely mereological account, we will adopt two further notions from Landman, namely *disjointness* (not overlapping) and *generator set*. One area of loose consensus in the semantics of countability, that was emphasized most notably in Landman (2011) is that one should not, usually, allow for overlap in the set of entities which one wishes to count. Landman's idea was that overlap leads to overdetermination of how many entities there are and that if this overlap cannot somehow be ignored, then counting goes wrong. The importance of non-overlap is also mentioned by Chierchia (2010), and via the notion of a "default" counting context in Rothstein (2010). The standard mereological notions of disjointness are given in (13) and (14):

$$DISJ(x, y) \leftrightarrow x \neq y \rightarrow x \sqcap y = \varnothing \tag{13}$$

$$DISJ(P) \leftrightarrow \forall x \forall y[(P(x) \wedge P(y) \wedge x \neq y) \rightarrow x \sqcap y = \varnothing] \tag{14}$$

Generator sets in Landman (2011), informally, play the role of what we have referred to here as *Ind* sets, namely the sets of entities that count as "one". However, Landman (2011) formally characterizes them in the following way:

> A generating set for X is a set $\mathbf{gen}(X) \subseteq X - \{\varnothing\}$ such that:
> $\forall x \in X : \exists Y \subseteq \mathbf{gen}(X) : x = \sqcup Y$

In other words, the a generator set should, when closed under sum, yield the set it generates. These two notions can be put together to form two reasonable *countability norms* which are inspired by Landman's (2011) notions of *disjointness* and *generator sets*:

Disjointness Condition: *Ind* sets should be (non-trivially) disjoint.

Generator Condition: *Ind* sets should be generator sets.

Now, provably, the property in (11) entails that one or the other of these norms must be violated. This should be clear from Figs. 3 and 4, but can also be demonstrated. The right hand side of (11) can only be satisfied if $x \neq y$, since $y \sqsubset x$. Either (i) $y \in Ind(P)$ or (ii) $y \in P$ and $y \notin Ind(P)$. If (i), then there are $x, y \in Ind(P)$ such that $y \sqsubset x$. Since $y \sqsubset x \leftrightarrow x \sqcap y \neq \varnothing$, it is not the case that $DISJ(Ind(P))$. If (ii), then there is a $y \in P$ and an $x \in Ind(P)$ such that

[6] This is, again, not absolute. For example, *table* seems to behave closer to fence insofar as two tables pushed together can count as "one" table.

Table 2. Examples of individuals and parts of individuals in the denotation of predicates

Noun class	Examples	Individuals	Parts of individuals
Superordinate artifacts	*kitchenware*, *Küchengerät-e*$_{+C,PL}$ ('kitchenware', German)	pestle, mortar, pestle $\sqcup$ mortar	pestle, mortar
Homogenous objects	*fence*, *fencing*	fence_1, fence_2 $\text{fence}_1 \sqcup \text{fence}_2$	fence_1, fence_2
Granulars	*rice*, *lentil-s*	grains of rice lentils	parts of grains, rice flour parts of lentils, lentil flour

$y \sqsubset x$ and $y \notin Ind(P)$. If $Ind(P)$ is disjoint, then there is also no $z \sqsubset y$ such that $z \in Ind(P)$. Hence, there can be no subset of $Ind(P)$, Y such that $\sqcup Y = y$, hence $Ind(P)$ is not a generating set for P.

Homogenous objects (*fence*) and superordinate artifacts (*furniture*) have the potential of being countable, since they do have non-empty *Ind* sets. However, countability can be undermined unless the overlap in their *Ind* sets is somehow ignored.

Granulars (*rice, lentils*) have the potential of being countable, since they have non-empty *Ind* sets. However, countability can be undermined because their *Ind* sets do not generate the entirety of their denotation (i.e. do not generate anything 'below' the granular level).

4.2 Beyond Mereology

It is at this point that it seems that a purely mereological analysis gives out. Superordinate artifacts and homogenous objects breach the *disjointness condition*, but some nouns in these classes are count nouns. Granulars breach the *generator condition*, but some nouns in these classes are count nouns.

In cases where the *disjointness condition* is violated, a noun may still be lexicalized as count (as with *fence* and *huonekalu* ('furniture', Finnish)) if some mechanism exists by which one can ignore overlap in an *Ind* set in such a way as to ensure only one counting result in any given context. At the very least, this seems to require that count nouns in the homogenous objects (*fence*) and superordinate artifacts (*huonekalu*) groups must be indexed in some way to either something akin to Rothstein's counting contexts (Rothstein 2010), or to a formal device such as Landman's "variants", where a variant of a generator set is a maximally disjoint subset (Landman 2011). Although a maximally disjoint subset (variant) can be specified in mereological terms, we nonetheless require a formal device which applies a single variant to an *Ind* set at a given occasion. For example, if a teacup and saucer count as two items of kitchenware on one occasion, then this formal device should make it possible that the cup and saucer sum count as a single item on another occasion.

In cases where the *generator condition* is violated, a noun may still be lexicalized as count (as with *lentil*) if one has a formal device that can explain why an *Ind* set can sometimes be taken as a counting base despite not generating the whole nouns denotation. We argued in Sutton and Filip (2016), that an explanation of this phenomena will need to be derived from a distinct form of context-sensitivity such as the one that underpins Chierchia's vagueness-based account of the mass/count distinction (Chierchia 2010). Chierchia points towards examples where what we have identified as the individuated units of granulars (the single grains, flakes etc.) fall in and out of the extensions of granular predicates depending on context. For example, a single grain of rice is sufficient in quantity to count as *rice* in contexts where someone has an allergy, but insufficient to count as *rice* when one is making paella. While this evidence is not sufficient to fully justify supervaluationism as applied by Chierchia, it does suggest that the *Ind* set for granulars is on looser grounds that the *Ind* sets in other categories. For example, for prototypical objects, homogenous objects, and superordinate artifacts, if $x \in Ind(P)$ at a context c, then $x \in P$ at all contexts c', however, for nouns such as rice, there are at least some contexts in which, if $x \in Ind(P)$ at c, it is possible that $x \notin P$ at some context c'. However, this does not imply that the individuated units for granulars are underspecified or vague. Minimally, therefore, we require another index to another form of context, or else a richer story about how extensions of granular nouns can vary from use to use.

5 Conclusions

In this paper we have identified a number of complications that arise in trying to establish the right formal tools to model the mass/count distinction in concrete nouns. We have argued that, as important as a theory of individuation is, the development of a theory of individuation does not entail that one has a theory of the mass/count distinction. Furthermore, we have argued that, even if one assumes an independently motivated theory of individuation, classical mereology is still insufficient for capturing the puzzling mass/count variation data for superordinate artifacts, homogenous objects and granulars.

We have concluded that, minimally, two dimensions of context sensitivity need to be incorporated into a mereological semantics. The first to formally remove overlap from an overlapping *Ind* set, the second to track the way in which the truth conditions of, especially, granular nouns shift in such a way as to change the position of the *Ind* set in the lattice or even remove it from the noun's denotation entirely in some situations.

Acknowledgements. This research was funded by the German Research Foundation (DFG) CRC991, project C09.

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